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Experiments with Potatoes on Muck Soil

John Bushnell

OHIO
AGRICULTURAL EXPERIMENT STATION
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CONTENTS

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EXPERIMENTS WITH POTATOES ON MUCK SOIL

JOHN BUSHNELL[1]

INTRODUCTION

There are about 150,000 acres of organic soil in Ohio, most of it in small tracts in the glaciated area, as shown in Figure 1. Some of the tracts, particularly the larger ones, have been drained for about 50 years and have been intensively cropped. Some of the smaller tracts, chiefly those difficult to drain, remain undeveloped.

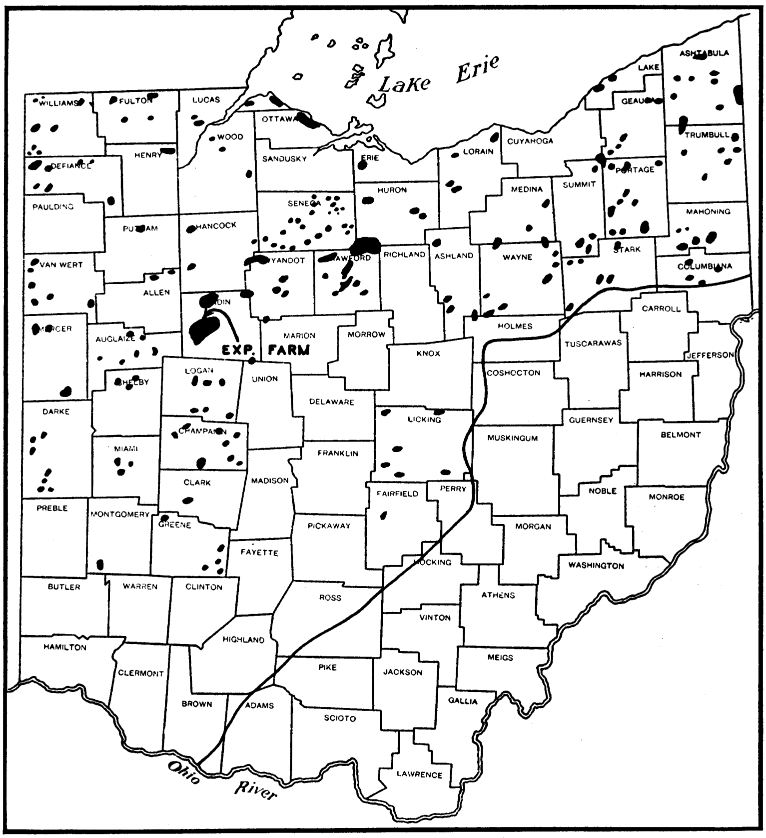


Fig. 1.—Distribution of muck and peat in Ohio. After Dachnowski (1)

Muck areas shown as black spots on somewhat exaggerated scale. Diagonal line shows the southern limit of glaciation

[1]**Acknowledgments.** The work at the Muck Crops Experiment Farm, McGuffey, has been under the immediate supervision of Donald Comin, assistant horticulturist, and Harry Obenour, foreman. To them is due much of the credit for the results reported here. J. P. Sleesman, assistant entomologist, who is studying insect problems of muck crops, has made many helpful observations and suggestions and at times assumed responsibility for potato experiments. The irrigation experiment was planned, installed, and operated under the direction of V. L. Overholt, associate agricultural engineer, and H. D. Brown, associate horticulturist.

Onions and celery have been the most important crops on the mucks in Ohio for many years. Relatively recently other vegetables, particularly frost-resistant crops such as carrots, lettuce, cabbage, and spinach, have increased in importance. Potatoes have been until very recently a minor crop, and even today few growers are using modern methods of producing potatoes on muck soils in Ohio.

There are at least three reasons for the slow development of potato production on muck: First, potato tops are injured by frost, and, therefore, the crop is more uncertain than frost-enduring vegetables. Second, potatoes from the muck have had a reputation for inferior quality. This reputation was probably based upon crops grown on poorly drained mucks with inadequate fertilizers; moreover, the fact that the adhering muck made the potatoes dark and unattractive may have added to this popular impression. With proper drainage, liberal fertilizers, and the use of modern cleaning machinery the market prejudice seems to be rapidly disappearing. The third reason for the slow development of potato production on muck is the large amount of special machinery which is necessary to handle potatoes by modern methods and the fact that this machinery is of no value for other crops. Only by relatively large scale operations can this special investment be used economically.

In spite of these limitations, there has been a considerable acreage of potatoes on muck soils for more than a decade in New York, Indiana, Iowa, and Minnesota. Ohio growers, starting more recently, have followed the practices developed in the older sections. The immediate impetus, however, to potato growing on muck in Ohio was the development of cleaning machinery, particularly of the brusher type. With satisfactory machinery now to be had, with fairly well established cultural practices to be followed, and with market prejudice diminishing, it seems that the production of potatoes on muck is very likely to increase.

The experiments reported here were conducted at the Muck Crops Experiment Farm, which was established in 1932. The general aim of the work has been to answer questions regarding cultural practices. The results in general show that the methods employed by careful growers are entirely sound but also emphasize that in several respects potatoes need to be handled differently on muck than on mineral soils.[2]

MUCK AS A SOIL FOR POTATOES

Before field experiments were started at the Muck Crops Farm preliminary tests in the greenhouse showed that muck was an excellent soil for potatoes. In muck the early growth of plants was much more rapid than in other types of soil (Fig. 2). In the four seasons that potatoes have been grown at the Muck Crops Experiment Farm, the plants have been characteristically large and vigorous. Unless injured by frost, the plants from May plantings completely covered the ground by late July. The main stems of the plants have usually been over 3 feet long. The leaflets are small, but the stems are so branched and the leaves consequently so numerous that the lower leaves usually die off from the shading of the dense foliage above.

The yields from the high-yielding plots at the Muck Farm (not including irrigated plots) have surpassed the yields of the high-yielding plots at other experiment farms in the State (Table 1). In New York similar differences in

[2]The methods of producing potatoes on mineral soils in Ohio are described by E. B. Tussing in ''Potato Growing in Ohio''. Ohio Agricultural Extension Service Bulletin 86, 1935.

favor of muck soils were reported by Hardenburg (3). Further evidence that organic soils are especially favorable for potatoes is found in the Census records, which show that the county with the highest average yield in 1929 was San Joaquin County, California, where the crop is grown on irrigated muck (Table 2).

Fig. 2.—Comparison of the early growth of Russet Rural plants in silt loam and in muck

TABLE 1.—Comparison of Yields for Three Seasons from High-yielding Plots at Experiment Farms on Three Diverse Soil Types in Ohio

Yields in bushels per acre. Irrigated plots not included

County ☞	Hardin			Washington			Wayne		
Type of soil ☞	Muck			Chenango sandy loam			Wooster silt loam		
Variety ☞	Irish Cobbler			Irish Cobbler			Russet Rural		
Season	Large	Small	Total	Large	Small	Total	Large	Small	Total
1932	292	30	322	274	27	301	245	8	253
1933	269	24	293	186	44	230	198	31	229
1934	452	35	487	228	37	265	320	10	330
1935	472	63	535	440	34	474	341	40	381
Average	371	38	409	282	36	318	276	22	298

TABLE 2.—Yield per Acre of Some Leading Potato Producing Counties of the United States

Data from the Census of 1930

State and county	Predominant type of soil	Total production	Average yield per acre
		Bu.	*Bu.*
California, San Joaquin*	Muck	3,816,849	326
Maine, Aroostook	Caribou silt loam	41,834,545	315
Idaho, Twin Falls*	Portneuf silt loam	1,900,542	276
New York, Suffolk	Sassafras silt loam	3,760,576	117

*Irrigated.

Fig. 3.—Excavation directly beneath potato plant showing roots distributed through the muck down to the zone of the snail shells. August 8, 1934.

Root development has been examined on the three types of soil listed in Table 1. On both of the mineral soils the roots were found to be largely confined to the plowed layer; they penetrated the subsoil, which is somewhat heavier than the surface soil, only sparsely and to a depth of about 20 inches. At the Muck Farm in 1934, with the water table below the bottom of the muck, the roots were likewise most abundant in the plowed layer, but they penetrated the subsoil freely and were found spread through the layer of snail shells on the clay at the bottom of the muck, about 30 inches deep. Figure 3 is a photograph of the side of a trench directly under a row of potatoes, and Figure 4 shows two blocks of muck (or peat) taken from the bottom of the muck, showing the abundance of potato roots in this layer containing the snail shells. These observations show convincingly that the subsoil of muck is far more favorable for potato roots than the subsoils of some good Ohio mineral soils.

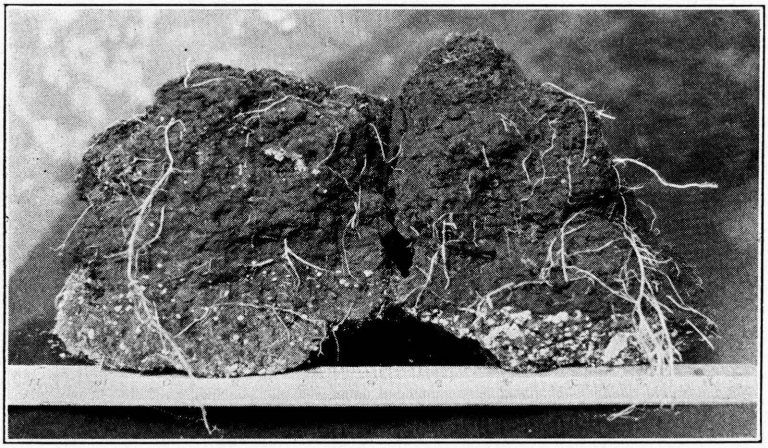


Fig. 4.—Potato roots in blocks of muck (or peat) from the bottom of the muck. The white particles are snail shells

THE MUCK CROPS EXPERIMENT FARM

DESCRIPTION

The Muck Crops Experiment Farm is located near McGuffey in Hardin County at the northern edge of the Scioto marsh, the largest area of muck in Ohio (see Fig. 1). Effective drainage of this marsh was begun in 1883 (1) and the soil has probably been continually cropped ever since. For many years the marsh has been an important onion producing area.

According to estimates of old residents of McGuffey, the muck at the time of drainage was about 8 feet deep. In 1911, test borings by Dachnowski (1) showed the muck to be over 5 feet deep, but, in 1932, a soil survey under the direction of G. W. Conrey showed the muck on the experimental tract to be only 40 inches deep at the south and 24 inches at the north side. Evidently, the muck is very much shallower now than at the time of drainage.

Continuous, intensive cultivation has resulted in a very fine texture of muck in the plowed layer. When dry, this fine muck drifts readily in the wind; during wind storms the sky is blackened by blowing muck. No comprehensive system of windbreaks has been established on the marsh as a whole. There are a few willow plantings, but each individual tract of onions is generally protected for a period after planting by temporary low windbreaks of various types. These measures are only partially effective, and the drifting of the muck constitutes one of the chief hazards of onion production. With potatoes, however, the drifting of the muck is not a very serious factor. In the writer's observations, the muck has not blown sufficiently to expose seed pieces, the sprouts or young plants covered by a drift seem to penetrate the drift fairly successfully, and a coating of muck on the leaves has not been noticeably injurious. Because potato plants grow very rapidly after emergence, they soon protect the surface of the muck from wind action.

The Experiment Farm tract consists of 10 acres adjacent to the large Cottonwood drainage ditch. In recent years the water level in the ditch has usually been below the bottom of the muck, so that the soil is well drained. The soil below the plowed layer is mostly black and hard, having large cracks and resembling a very soft coal in appearance. The lumps can be broken by hand, and potato roots penetrate them freely. Three to 6 inches of the bottom of the muck are mixed with snail shells (see Figs. 3 and 4). Underneath is a typical, heavy, calcareous, blue clay. The plowed layer of soil has a pH of about 5.7.

The tract is part of a large field which has probably been cropped continuously either to corn or onions for about 50 years. For several years prior to 1932 the field was in corn.

INITIAL METHODS OF GROWING POTATOES

At the outset of the experimental work in 1932 there were no Ohio muck farmers who were consistently successful in producing potatoes. Consequently, there were no established practices to follow in Ohio, and no published reports were found from other states giving details of their cultural practices. The methods followed at the Experiment Farm were, therefore, the same as those on mineral soils with three exceptions: First, it was presumed that this muck, like muck in general, was deficient in potash, and, therefore, a high potash fertilizer was used; second, it was presumed that Cobblers could be successfully grown if planted in May or June; and, third, since April plantings would be subject to injury by late spring frosts, the first plantings were delayed until early May.

Experience has shown that three serious mistakes were made in the initial procedures: First, the early May plantings of Cobblers were too early, damage from frost in June being very severe in 1932 and in 1933. Second, the use of an ordinary Hallock type weeder dragged out or disturbed many of the young plants. Finally, spraying at intervals of about 10 days did not adequately cover the foliage; the plants grew so rapidly that several layers of leaves developed in 10 days and the upper leaves spread over the lower leaves sufficiently to prevent spray from reaching them.

By 1934 these difficulties were duly appreciated. Planting of the main crop was delayed until May 22; the plants were sprayed every week during June and July; the weeder was equipped with runners to regulate the depth, and the weeding was done with special care to avoid breaking the small plants. With these precautions and with no fall frosts until late September, the yields of some of the plots have exceeded 500 bushels per acre.

POTATO EXPERIMENTS

VARIETIES

The varieties grown on muck in Ohio and adjacent states are chiefly Irish Cobblers and Rurals, the same as on mineral soils. On mineral soils the Cobbler is definitely an early variety, succeeding only when planted early and maturing in about 120 days. The Rurals (both Russet and White) are main-crop varieties maturing in about 160 days. On the muck soils, however, this distinction almost disappears, partly because frosts in the late spring and early fall shorten the growing season and partly because early varieties may prolong their growing season on muck. In 1934, at the Muck Crops Experiment Farm, Cobblers planted May 4 did not die down until about September 25, thus growing for nearly 150 days. On the other hand, in 1935 Cobblers were killed by the hot weather of early September on muck just as on other soils.

In the comparison of Cobblers and Rurals at the Experiment Farm the Rurals have given the higher total yields in every test, except the last planting of 1934 where the Rurals were immature (Table 3). The greatest difference was in 1933 when the Rurals recovered from the freeze of June 16 much better than did the Cobblers. The Cobblers seem to be more sensitive than Rurals to unfavorable conditions on the muck, just as they are on mineral soils. It is commonly observed that flea beetles and leaf hoppers are more injurious to Cobblers than to Rurals; hence, Cobblers require more thorough spraying. The failure to spray adequately may account in part for the relatively low yields of Cobblers in 1932 and 1933. With good spraying in 1934 and 1935, the yield of No. 1 grade from the Cobblers was actually higher than from the Rurals in four out of the six plantings.

Obviously, it cannot be said from the yield data of Table 3 that one variety is distinctly superior to the other, but from incidental observations and general information, together with the yield records, the following practical conclusions may be drawn:

1. With good culture and a favorable growing season of more than 120 days, such as 1934 and 1935, the Rurals are likely to develop serious growth cracks whereas Cobblers do not. Typical culls from both varieties are shown in Figures 5 and 6.

2. With a favorable growing season of 100 to 120 days the Rurals will not mature, but the crop will be marketable if carefully handled and will yield about the same as Cobblers. The Cobblers will be practically mature in a season of this length.

3. For very late plantings, which have a growing period of less than 100 days, the Cobblers are likely to give the higher yield, as well as the more mature tubers.

4. With unfavorable conditions due to summer frosts, severe drouth, or inadequate spraying, the Rurals are likely to survive the unfavorable conditions more successfully than Cobblers and thus give higher yields.

5. In Ohio, certified seed of Rurals is usually cheaper than certified seed of Cobblers because the Rurals come from Michigan or New York whereas the bulk of the Cobblers come from Maine or North Dakota.

As a practical rule then, Cobblers can be planted earlier or later than Rurals but they must be more frequently and thoroughly sprayed. Rurals do not require as careful culture as do Cobblers, but they require a little longer growing season to reach marketable size and may need to be harvested before maturity to avoid losses from growth cracks.

TABLE 3.—Comparative Yield of Irish Cobblers and Rurals

Mostly single rows, 300 feet long; yields in bushels per acre

Date planted	Irish Cobblers					Rurals				
	Large*	Small	Culls	Total	Date tops were dead	Large*	Small	Culls	Total	Date tops were dead or frozen
	Bu.	*Bu.*	*Bu.*	*Bu.*		*Bu.*	*Bu.*	*Bu.*	*Bu.*	
1932—May 4	259	41	†	300	Aug. 25	301	13	†	314	Sept. 16
June 2	306	27	....	333	Sept. 16	232	36	....	268	Sept. 16
1933—May 3‡	129	23	20	172	Aug. 23	285	13	44	342	Sept. 22
June 6	281	45	18	344	Sept. 20	343	19	27	389	Oct. 14
1934—May 4	375	20	38	433	Sept. 20	237	21	190	448	Sept. 28
May 22	322	13	15	350	Sept. 28	292	35	44	371	Sept. 28
June 7	247	23	23	293	Sept. 28	298	23	45	366	Sept. 28
June 20	304	24	21	349	Sept. 28	187	24	11	222	Sept. 28
1935—May 3	367	63	105	535	Sept. 5	451	41	68	560	Sept. 24
May 24	310	29	26	365	Sept. 20	265	33	100	398	Oct. 3
Average of May 3 and 4‡	334	41	48	423	Sept. 6	330	25	86	441	Sept. 23
Average of May 22 and June 7	293	27	17	337	Sept. 22	286	30	42	358	Sept. 30

*"Large" tubers are those over 1⅞ inches in diameter. They were graded to U. S. No. 1 standard after 1932.

†Culls not sorted out in 1932 but included with the large tubers.

‡The planting May 3, 1933, was severely injured by frost on June 14. The Rurals recovered better than the Cobblers. This planting is not included in the averages.

White Rurals compared with Russet Rurals.—The Russet Rural is the most common late variety in Ohio. Comparisons on silt loam soil at Wooster have shown that some strains of the White Rural yield as well as the Russet. There seems to be a slight market advantage in favor of the White; hence, in recent years the acreage of White Rural has been increasing. When grown on muck, there is a further advantage in that the smooth skin of the White Rural cleans more readily than the rougher skin of the Russet.

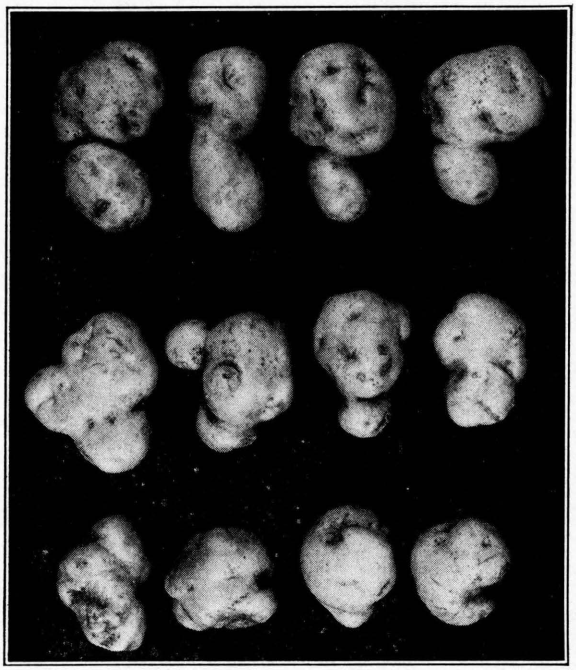


Fig. 5.—Irregular second growth in Cobblers, 1934. Cobblers usually have less than 10 per cent of cull tubers

The name "White Rural" is applied to a number of very similar, but probably distinct, varieties. The differences are commonly recognized in New York where the White Rural is an old established variety and the distinct strains are locally named. A few of the strains from New York were compared in 1933 with one strain from Michigan and two from Wisconsin, all reputed to be high-yielding types of White Rurals. The results are given in Table 4. Although only one year's data, they agree with similar tests at Wooster and show that some strains of the White Rural yield as well as the Russet Rural. From these limited data, the Pioneer and Heavyweight strains are recommended for the present. In recent years a considerable quantity of these strains has been certified in New York; whereas the quantity of White Rurals from Michigan has been relatively small.

TABLE 4.—Strain Test of White Rurals, 1933

Planted June 6. Yield from single rows 200 feet long converted to bushels per acre

Sample from	Name of strain	Yield per acre		
		Large	Small	Total
		Bu.	*Bu.*	*Bu.*
New York	Pioneer	433	18	451
New York	Heavyweight	409	21	430
Michigan	....	404	16	420
New York	Rural No. 9	361	20	381
New York	Rural No. 9	335	23	358
New York	Rural New Yorker	332	21	343
Wisconsin	....	301	16	317
Wisconsin	....	280	20	300
Michigan	Russet Rural (check)	402	20	422

Fig. 6.—Characteristic deep growth cracks in Rurals. In the early plantings of 1934 over 40 per cent of the tubers comprised culls of this type

New varieties.—The U. S. Department of Agriculture has recently introduced two new varieties, Katahdin and Chippewa, which may prove to be of special value on muck. Both mature a week or two later than the Irish Cobbler. Their chief advantage is in the shallow eyes and clear, white skin of the tubers.

As shown in Table 5, the Katahdin outyielded the Irish Cobbler three seasons out of four. The Chippewa was first available in 1934 and has yielded approximately the same as the Irish Cobbler, the differences being less than 30 bushels per acre.

TABLE 5.—Newer Varieties Compared with Irish Cobbler

Yield of No. 1 grade tubers in bushels per acre; mostly single-row plots

Variety	Date planted						
	June 2, 1932	May 3, 1933	May 4, 1934	May 22, 1934	June 7, 1934	June 20, 1934	May 24, 1935
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Irish Cobbler	259	130	375	322	247	304	310
Late Cobbler	283	364	*	298	275	317	282
Katahdin	300	332	349	263	*	247	361
Chippewa	*	*	*	316	276	285	325
Warba	*	*	*	*	*	*	370

*Seed not available for these tests.

The chief weakness of the Katahdin is a tendency to develop deep creases at the bud end of large tubers. This has been noted on mineral soils as well as in these muck tests. The deep creases are as difficult to clean as the deep eyes of the Cobbler. The Chippewa has been superior to the Katahdin in this respect. The eyes at the bud end of large tubers were not shallow but still not so deep as to give creases. As the tubers of both these varieties are much more attractive than those of any of the older varieties, they are likely to become prominent on muck soils.

The Warba is an extra early variety introduced by the Minnesota Experiment Station. The eyes on the tubers are as deep as those of the Cobbler. It was first tested at the Muck Crops Farm in 1935 and in this test outyielded the Cobbler (Table 5).

The Late Cobbler was introduced by F. S. Hollenbeck of Tully, New York, about 10 years ago. It has the characteristics of the Irish Cobbler, except that the plants are more vigorous and mature about 2 weeks later. As also shown in Table 5, it has yielded somewhat better than the Irish Cobbler in four tests out of six. It is a vigorous, high-yielding variety but has the typical deep eyes of the Cobbler.

DATE OF PLANTING

From the data of Table 3 it is evident that the largest yields have come from the earliest plantings, except in 1933, when the early plantings were injured by severe frosts in June. On the other hand, satisfactory crops of Cobblers have been obtained by planting in late May or June. The Rurals have been more sensitive to time of planting. Early May plantings, although high in yield, have frequently developed growth cracks in the tubers; plantings after the middle of June have been immature at frost. The results are very different from experience on mineral soils in Ohio, where the Cobbler succeeds only when planted very early and the Rural rarely shows growth cracks and usually matures if planted by June 20.

Although the highest yields of the last two seasons were from the early May plantings, the danger of losses from June frosts, such as occurred in 1933, is an argument for delaying planting until late May. From the limited data at hand, it seems that the latter half of May is the safest date for planting both Cobblers and Rurals on muck.

FERTILIZERS

Potatoes are included in a general fertilizer experiment with several other vegetable crops. The crops are grown in a 3-year rotation: potatoes, onions, and a collection of other crops. All of the plots are thus fertilized and cropped every year.

The fertilizers are made up of sulfate of ammonia, 20 per cent superphosphate, and muriate of potash. The mixtures are broadcast in April prior to planting the onions and a month or more before the planting of potatoes. Each fertilized plot is 1/40th acre, and, since potatoes occupy only one-third of each plot, the potato plots are 1/120th acre. The entire series is quadruplicated, with uniformly fertilized check plots every fourth plot.

The numerous checks and a systematic distribution of the other treatments make it possible to detect soil variations. The yield records show that the block is fairly uniform except at the extreme east and west, where there are usually some drifts of wind-blown muck in the spring which perhaps cause the lower yields of potatoes. Fortunately, the east and west plots are part of the system of check plots, and for present purposes they are disregarded. The average yield of the check treatment (3-9-18 fertilizer), as given in Table 6, is calculated from 12 check plots distributed through the block. As frost caused considerable injury in both 1932 and 1933 the yields of 1934 and 1935 are of most interest; hence, they are summarized separately in Table 7.

The fertilizer treatments are arrayed in these tables to show the effects of the individual fertilizer constituents.

Nitrogen fertilizer has not had any distinct effect on the yield of potatoes. The 0-9-18 mixture produced as high yields the last 2 years as any of the nitrogen mixtures.

Phosphoric acid has produced small but consistent increases. In each of the four seasons the plots with 3-9-18 outyielded those with 3-0-18. The average increase of the No. 1 grade tubers, however, has been only 9 bushels per acre. Curiously, raising the phosphoric acid to 18 per cent (3-18-18) increased the average yield another 9 bushels. Each of these 9-bushel increases has cost nearly 4 dollars per acre for the fertilizer (337.5 pounds of 20 per cent superphosphate for each 9 per cent in the mixture). Whether phosphoric acid has been profitable or not, then, has depended considerably upon the price of potatoes. It is obviously difficult to make practical recommendations regarding the use of phosphoric acid where the increases in yield are as small as they have been here.

Potash is the one constituent that has given large increases in yield. This has been particularly true in the last 2 years. It may be noted from the average yield of No. 1 grade tubers in 1934 and 1935, as given in Table 7, that the increases for each increment of potash fertilizer were as follows:

Per cent potash	Increase in bushels
9	160.5
18	69.3
27	35.3
36	24.2

TABLE 6.—Yields of Irish Cobblers from Fertilizers Broadcast at the Rate of 750 Pounds per Acre

Planted in May. Average yield of four replicated plots in bushels per acre, except the 3-9-18 which is the average of 12 plots

Year	Large Bu.	Culls Bu.	Small Bu.	Total Bu.	Large Bu.	Culls Bu.	Small Bu.	Total Bu.	Large Bu.	Culls Bu.	Small Bu.	Total Bu.	Large Bu.	Culls Bu.	Small Bu.	Total Bu.
Nitrogen series																
Fertilizer ☞	0-9-18				3-9-18				6-9-18				9-9-18			
1932	239.1	*	24.1	263.2	249.6	....	24.5	274.1	243.9	....	25.6	269.5	254.3	....	22.0	276.3
1933	91.7	*	27.8	119.4	98.7	....	26.6	125.3	99.3	....	28.3	127.6	91.9	....	27.7	119.6
1934	364.9	38.6	32.7	436.2	359.7	43.7	36.2	439.6	352.1	45.9	35.5	433.5	349.9	51.9	33.6	435.4
1935	298.8	27.7	55.6	382.0	288.7	29.9	56.4	374.9	283.9	29.3	53.7	366.9	299.0	28.8	57.3	385.1
Average	248.6	....	35.0	300.2	249.2	....	35.9	303.5	244.8	....	35.8	299.4	248.8	....	35.1	304.1
Phosphoric acid series																
Fertilizer ☞	3-0-18				3-9-18				3-18-18				3-27-18			
1932	244.9	....	22.5	267.4	249.6	....	24.5	274.1	255.9	....	25.0	280.9	260.6	....	26.2	286.8
1933	88.1	....	27.9	116.0	98.7	....	26.6	125.3	102.4	....	27.7	130.1	104.6	....	28.0	132.6
1934	348.3	33.5	33.2	415.0	359.7	43.7	36.2	439.6	372.5	39.6	41.3	453.4	356.9	41.6	35.9	434.4
1935	279.7	20.6	53.7	353.9	288.7	29.9	56.4	374.9	304.3	30.1	53.8	388.1	316.5	32.9	55.8	405.2
Average	240.3	....	34.3	288.1	249.2	....	35.9	303.5	258.8	....	36.9	313.1	259.7	....	36.5	314.8
Potash series																
Fertilizer ☞	3-9-0				3-9-9				3-9-27				3-9-36			
1932	203.9	....	27.3	231.2	228.4	....	26.5	254.9	248.9	....	21.0	269.9	258.1	....	27.1	285.2
1933	52.8	....	29.4	82.2	69.5	....	25.7	95.2	95.1	....	29.2	124.3	104.9	....	24.6	129.5
1934	103.1	21.3	40.4	164.8	275.0	30.1	39.3	344.4	393.5	58.1	35.5	481.1	405.3	70.0	33.9	509.1
1935	85.6	5.3	48.1	138.6	234.8	21.0	52.3	308.0	325.5	35.6	56.0	417.1	362.0	32.3	53.5	447.8
Average	111.4	....	36.3	154.2	201.9	....	35.9	250.6	265.8	....	35.4	324.6	282.6	....	34.8	342.9
Other treatments																
Fertilizer ☞	0-0-0				6-18-36											
1932	195.3	....	28.7	224.0	264.9	....	24.8	289.7								
1933	52.1	....	26.0	78.1	123.8	....	28.2	152.0								
1934	147.8	18.3	36.5	202.6	406.8	47.6	35.4	489.8								
1935	85.8	5.2	45.3	136.2	340.8	36.8	53.0	430.5								
Average	120.3	....	34.1	160.2	284.1	....	35.3	340.5								

*Culls over 1⅞ inches in diameter included with "large" tubers in 1932 and 1933. In 1934 and 1935 the "large" tubers were graded to U. S. No. 1 standard.

TABLE 7.—Effect of Fertilizers on Number and Size of Tubers

Fertilizer formula	Yield per acre No. 1 grade			Average weight of No. 1 grade tubers		Average number of tubers per hill					
						Large*		Small		Total	
	1934 Bu.	1935 Bu.	Average Bu.	1934 Oz.	1935 Oz.	1934 No.	1935 No.	1934 No.	1935 No.	1934 No.	1935 No.
Nitrogen series											
0-9-18	364.9	298.8	331.9	4.80	4.37	4.47	3.98	1.09	1.85	5.56	5.83
3-9-18	359.7	288.7	324.2	4.70	4.37	4 58	3.87	1.21	1.88	5.79	5.75
6-9-18	352.1	283.9	318.0	4.78	4.33	4.43	3.84	1.18	1.79	5.61	5.63
9-9-18	349.9	299.0	324.5	4.42	4.28	4.85	4.07	1.12	1.91	5.97	5.98
Phosphoric acid series											
3- 0-18	348.3	279.7	314.0	4.96	4.26	4.11	3.76	1.11	1.79	5.22	5.55
3- 9-18	359.7	288.7	324.2	4.70	4.37	4.58	3.87	1.21	1.88	5.79	5.75
3-18-18	372.5	304.3	338.4	4.77	4.34	4.60	4.10	1.38	1.79	5.98	5.89
3-27-18	356.9	316.5	336.7	4.83	4.40	4.40	4.24	1.20	1.86	5.60	6.10
Potash series											
3-9- 0	103.1	85.6	94.4	3.87	3.38	1.71	1.42	1.35	1.60	3.06	3.02
3-9- 9	275.0	234.8	254.9	4.22	4.13	3.85	3.28	1.31	1.78	5.16	5.06
3-9-18	359.7	288.7	324.2	4.70	4.37	4.58	3.87	1.21	1.88	5.79	5.75
3-9-27	393.5	325.5	359.5	4.72	4.48	5.10	4.28	1.19	1.87	6.29	6.15
3-9-36	405.3	362.0	383.7	5.36	4.78	4.73	4.39	1.13	1.78	5.86	6.17
Other treatments											
0- 0- 0	147.8	85.8	116.8	3.79	3.45	2.34	1.40	1.22	1.51	3.56	2.91
6-18-36	406.8	340.8	373.8	5.25	4.61	4.62	4.35	1.18	1.77	5.80	6.12

*Includes the large-sized culls.

It may also be noted that the 6-18-36 fertilizer, listed as the last treatment in Tables 6 and 7, has given essentially the same average yield as the 3-9-36, which is further evidence that 36 per cent potash was somewhat superior to 27 per cent.

In regard to the effect of fertilizers on number and size of tubers (Table 7) the average yield of small tubers remained fairly constant at about 35 bushels per acre throughout all the treatments. The small increases in yield from the use of phosphoric acid have been due to increase in number of tubers per hill rather than in the size of tubers; whereas the increases from potash have been due to an increase in both number and size.

Hollow heart has not been found except in the very largest tubers from the high-potash fertilizers. In 1934, 20 tubers, each weighing over 20 ounces, were cut and 11 of the 20 had small cavities. Similarly, 50 tubers weighing from 16 to 20 ounces were cut and only two had hollow heart. These 70 tubers were the largest from the entire fertilizer experiment which covers more than half an acre. In other words, there were only 13 with hollow heart in the 70 largest tubers from about 175 bushels. In previous seasons, with smaller yields and smaller size tubers, there was no hollow heart found whatever.

The practical conclusion from the experiment as a whole is that the potash, and only the potash, has been distinctly profitable as a fertilizer. It is true that phosphoric acid is necessary for maximum yields, but the benefits from phosphoric acid in the fertilizer have been so small as to make its use doubtful economically. A recommendation, therefore, would be either a potash fertilizer alone supplying 270 pounds of potash (K_2O) per acre or a mixture containing a small proportion of phosphoric acid, such as an 0-9-36, at the rate of 750 pounds per acre.

DEPTH OF PLANTING AND CONTROL OF RHIZOCTONIA

In view of the fact that it is easy to plant deeply in muck and the fact that the sprouts penetrate readily, it seemed that there might be some advantage in planting deeper than on mineral soils. This was tested three seasons, with the result that the highest yield each year was from the rows planted at a depth of 3 inches (Table 8).

Presumably, the lower yield from the deeper planting was due to Rhizoctonia injury to the plants. In 1935, 10 hills from each planting were dug and examined on June 12. The hills from seed planted a greater depth than 3 inches were found to be increasingly infected (Table 9).

In these tests the depth of the seed was measured from the levelled surface of the soil to the top of the seed, but actually the seed was not covered to this depth at the time of planting. As one means of escaping Rhizoctonia injury, the seed was covered only about an inch and then the rows filled as the young plants emerged. To cover shallow with the planter, the covering disks were removed and replaced by a roller about 6 inches wide. No tests were made to see if this method was actually effective in reducing Rhizoctonia here, but it has been used on all the experimental plantings and excellent stands have been obtained.

TABLE 8.—Effect of Depth of Planting on Yield

Irish Cobbler planted with Iron Age Planter in 1932 and 1933; planted by hand in 1935. Average yield in bushels per acre of duplicate rows, 300 feet long in 1932 and 1933 and 30 feet long in 1935

Depth to top of seed pieces In.	Average yield Large Bu.	Small Bu.	Total Bu.
Planted May 4, 1932			
2	266	33	289
3	292	30	322
3½	262	20	282
4	255	26	281
4½	213	16	229
Planted May 5, 1933			
2	120	8	128
3	137	14	151
4	123	4	127
5	109	13	122
Planted May 4, 1935			
2	512	52	564
3	628	33	661
4	514	32	546
5	495	25	520
6	471	39	510

TABLE 9.—Condition of Plants on June 12 in Depth-of-planting Experiment

Sixty hills from each depth measured for height; twenty hills examined for Rhizoctonia on stems

Depth to top of seed pieces	Average height of plants	Percentage of hills with Rhizoctonia injury to stems: Moderate size lesions	Stems girdled
In.	*In.*	*Pct.*	*Pct.*
2	5.5	5	5
3	5.0	5	0
4	4.1	5	15
5	2.7	20	35
6	2.4	30	40

The only exceptions have been in special tests where seed coated with sclerotia of Rhizoctonia have been planted without previous treatment to kill the disease. In preliminary tests with such seed 75 per cent of the young plants had Rhizoctonia lesions on the stems. Treatment of the seed either with the old standard bichloride of mercury or with the newer yellow oxide of mercury gave good control; less than 5 per cent of the young plants had lesions. In spite of the fact that the muck itself contains sufficient Rhizoctonia to infect the tubers almost invariably, it appears that the young plants are not likely to become infected from this source when the seed is properly planted.

SPACING OF HILLS

The spacing of hills in the row has less effect on yield than upon the size of tubers. If the hills are too close many of the tubers are too small; if the hills are too far apart some of the tubers are too large. A preliminary test in 1932 showed that, with a yield of about 300 bushels per acre, the spacings of 8, 10, or 12½ inches between hills gave practically the same yield of marketable size tubers (Table 10). Most of the experimental plots since 1932 have been planted 10 to 11 inches between hills with satisfactory results. A spacing of 10 inches in rows 32 inches apart requires about 21 bushels of seed per acre, when the seed is cut into pieces weighing about an ounce each.

TABLE 10.—Spacing of Hills

Irish Cobbler planted May 4, 1932. Rows 32 inches apart. Average yield in bushels per acre of duplicate single rows 300 feet long

Distance between hills	Large	Small	Total
In.	*Bu.*	*Bu.*	*Bu.*
6	259	46	305
8	281	40	321
10	288	25	315
12½	285	22	307

IRRIGATION

The aim of the irrigation experiment has been to compare overhead irrigation (sprinkler type) with subirrigation and unirrigated plots. Distinct benefits were obtained from overhead irrigation in 1932 but not from subirrigation (Table 11). It was then found that water applied as subirrigation—by means of tile laid on the clay at the bottom of the muck—was spreading widely over the surface of the clay, part of it watering the section designed to be unirrigated but most of it escaping into the drainage ditch. Early in the spring of 1934, sheet iron partitions were placed in the muck around the subirrigated sections to confine the water.

TABLE 11.—Results from Irrigation of Irish Cobblers Planted in May

Type of irrigation	Yields in bushels per acre*						Average 1934 and 1935	
	1932		1934		1935			
	No. 1 grade	Total	No. 1 grade	Total	No. 1 grade	Total	No. 1 grade	Total
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
None	376	403	450	515	291	375	371	445
Overhead sprinkler	480	502	493	550	324	420	409	485
Subirrigation	369	396†	495	553	358	452	427	503

*1933 data not included because the crop was very seriously injured by June frost.
†The subirrigation was not successful in 1932, as explained in the text.

The muck is about 32 inches deep throughout the irrigated area. The depth of the water table in the subirrigated section is determined in small wells made of vertical tile. Beginning June 21, 1934, the subirrigation was applied two or three times each week, raising the water level each time to 24 to 22 inches below the surface of the muck. In spite of the partitions, the water level was down to 28 or 30 inches the day after irrigating.

As 1934 was a season of high yields on unirrigated muck, the increases from irrigation were less than 50 bushels per acre. Since 1935 was a wet season, irrigation water was applied only during June; nevertheless the increases from subirrigation were about 70 bushels per acre. The largest increase was in 1932, a relatively dry season, when the overhead irrigation increased the yield 100 bushels per acre.

One effect of raising the water table to a level about 24 inches below the surface has been to confine the potato roots to the upper 20 inches of the muck. The plants thus subirrigated have died earlier, but in spite of the earlier maturity have yielded as much or more than those with overhead or no irrigation.

The results as a whole show that, even in years with well distributed rainfall as in 1934 and 1935 (Table 11), there is still some benefit from irrigating during the brief dry periods. From the fact that subirrigation was successful here when precautions were taken to confine the water to the experimental area, it appears that subirrigation would be entirely feasible on a field scale on muck underlaid with a level subsoil of impervious clay if some measures were taken to dam the drainage ditches at proper levels. One point to be remembered in irrigating potatoes is that the roots are very sensitive to standing water and are likely to be killed if submerged for more than a day.

SPRAYING FOR INSECT CONTROL

Insects, particularly leaf hoppers and flea beetles, have been abundant all seasons. In 1932 an unsprayed plot yielded 152 bushels per acre; the adjacent sprayed plot yielded 306. In 1934, the unsprayed portion of a late June planting yielded 196 bushels per acre, and the sprayed portion yielded 287. Omitting half of the sprays from a May planting in 1934 resulted in a decrease of 100 bushels per acre (Table 12). Evidently, spraying or some other means of insect control is essential for high yields.

TABLE 12.—Results of Spraying and Dusting, 1934

Irish Cobblers planted May 20th; sprays and dusts applied the same days and at intervals of 7 to 10 days. Average yield per acre of triplicated plots

Treatments	Yield
	Bu.
Bordeaux spray*	347
Copper-lime dust	345
Alternate Bordeaux sprays omitted	247

*Bordeaux spray was a 4-6-50 mixture. The copper-lime dust was 20 pounds of monohydrated copper sulfate freshly mixed with 80 pounds of hydrated lime.

In order to cover the foliage properly it has been found advisable to spray at weekly intervals during the period of rapid growth. Later, when the plants fill the rows, the intervals have been 10 days or more. At this stage there is some injury to the tops from the wheels of the sprayer. No estimates of this injury have been made at the Experiment Farm, but Fitch (2) reports that in commercial fields in Iowa the yield of the injured rows was reduced 50 bushels per acre in one instance and 75 bushels in another instance below the yield of the uninjured rows. To avoid this injury and the resulting complications in experimental work, the plots at the Experiment Farm have been sprayed by hand with a long hose connecting with a power sprayer at the edge of the field. Although this procedure is hardly practical for field operations, methods which will minimize the injury, such as the use of rubber tires and wide booms, are obviously important.

The use of dusts to control insects on potatoes is not common in Ohio largely because the dusts must be applied late in the evening or early in the morning. In one test copper-lime dust gave practically the same control as the standard Bordeaux spray (Table 12). The details of this test were published previously (6).

FROST PREVENTION AND RECOVERY OF FROSTED PLANTS

Although no experiments on frost prevention have been conducted at the Muck Crops Farm, the problem is of such importance that a brief review of the work of others seems justified. To judge from the literature, no entirely satisfactory method of preventing frosts on muck has yet been devised.

There are occasional reports in the popular literature of the use of heat to ward off frost for potatoes but not on muck, for the risk of setting fire to muck is too great.

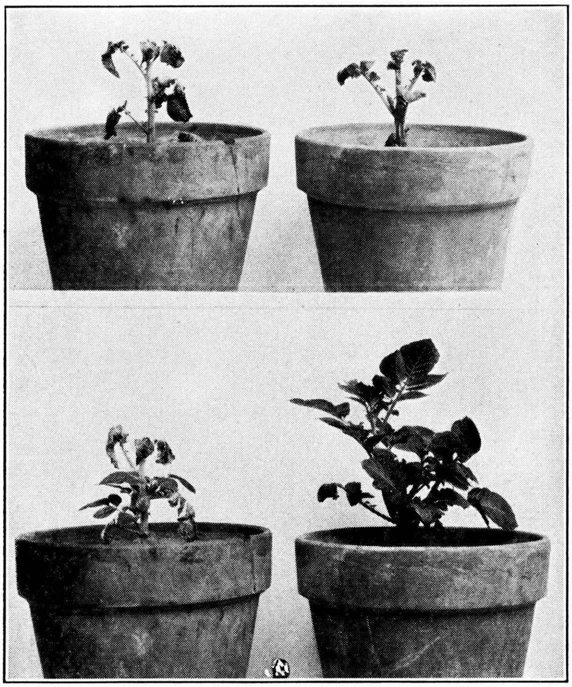
Harmer (4) recently summarized the methods and principles of frost prevention on muck. He pointed out that muck has a low heat capacity and is a poor conductor of heat. Consequently, the surface cools rapidly at night, the heat below being retained. The air above the muck on a still cold night is much colder at the surface than a few feet above. Harmer stated that on occasions the air was 2 degrees Fahrenheit warmer for each foot of elevation for a few feet above a muck. Any method of moving or stirring the air thus tends to mix the cold surface air with the warmer air above. Any method of increasing the heat conduction of the muck also tends to warm this layer of cold air near the surface; therefore, compact, moist muck is more effective in warming the air than a loose, dry muck.

Harmer has tested some methods of stirring the air to mix the cold surface air with warmer air above but at the time of his report had no practical recommendation to offer.

When young plants are severely frosted, their recovery is distinctly aided by the seed piece. If the seed piece has rotted the plants are likely to die. As a demonstration, the seed pieces were removed from some greenhouse plants about 8 inches tall. These plants together with some with seed pieces intact were placed outside in April to freeze and then brought back into the greenhouse. The leaves were completely frozen but the stems were only partly killed back. The value of the seed piece in the recovery is illustrated by the plants of Figure 7.

Kimbrough and Costa (5) found that young plants with relatively large seed pieces (weighing 1.5 or 2 ounces) recovered more successfully than those with small seed pieces. They also found that, if the plants had reached a stage where tubers were the size of marbles, the plants failed to recover sufficiently to produce a crop, even though the seed pieces weighed 2 ounces and were intact.

At the Muck Crops Experiment Farm in 1933 after the severe frost of June 14, there was very poor recovery even though most of the seed pieces were found to be intact and tubers had not formed. In this instance there was a heavy infestation of leaf hoppers and flea beetles. Prior to the frost the sprays at intervals of 10 to 12 days evidently failed to cover adequately the rapidly growing foliage, and, in consequence, the insects were abundant on June 14. After most of the leaves were killed by the frost, the insects were found to be concentrated on the new growth. To forestall this type of injury from insects, it is obviously essential to spray the rapidly growing young plants frequently enough to cover all of the new foliage at each spray.



Without seed piece With seed piece

Fig. 7.—Frost injury and recovery of young potato plants. ***Upper*****—Plants grown in greenhouse and frozen by exposure to outside temperature February 17, 1933 (one plant with seed piece removed).** ***Lower*****—The same plants 2 weeks later.**

The present recommendations to minimize injury from spring frosts may be briefly summarized as follows:

1. Delay planting until the last of May if late spring frosts are more likely to be serious than early fall frosts.

2. Take precautions to insure the seed surviving in the soil without rotting.

3. Roll and pack the soil rather than leaving it loose.

4. Spray young plants frequently to control leaf hoppers and flea beetles as completely as possible.

THE POSSIBILITY OF PRODUCING SEED POTATOES ON MUCK IN OHIO

In Ohio as a whole there are perhaps 30,000 acres of Irish Cobblers planted annually. The Census figures and crop estimates do not differentiate between early and late crops in Ohio; hence, this is merely an estimate. Whatever the acreage may be, it is planted largely with seed purchased annually from states to the north, much of it coming from Maine or North Dakota. The Ohio spring-crop Cobblers grown on mineral soils are unsatisfactory for seed the following year, partly because they are likely to be considerably diseased but more because they produce an excessive number of sprouts and the individual sprouts are too weak to develop into sturdy plants. On the muck soils in Ohio the date of planting Cobblers is about the same as the date of planting for certification in Maine and North Dakota (that is, the last of May). If free from disease the crop from the muck would be expected to be entirely satisfactory for seed.

From a plant pathologist's viewpoint, however, there are at least three objections to certifying seed potatoes on muck in Ohio. First, the symptoms of virus diseases do not appear distinctly, with the result that diseased plants cannot be clearly distinguished from healthy ones. As an illustration, a sample of Cobblers known to contain at least 20 per cent of leaf roll was planted in 1933 at the Muck Crops Experiment Farm, and it was impossible to detect the diseased plants in the early stages of growth by ordinary field examination. Second, virus diseases spread more rapidly under Ohio conditions than in the cooler North; hence, if there were a few infected plants in a field and particularly if these were not rogued out early in the season, there might result a considerable infection of the crop. Third, muck potatoes are usually coated with Rhizoctonia.

From a grower's viewpoint the long rotations that are advisable to insure good certified seed are not adapted to the intensive cropping usual in muck production. Moreover, suitable storages would have to be provided.

All of these objections, however, might be outweighed by the high price which Cobbler seed potatoes usually bring. If special methods could be devised for controlling diseases, it might prove feasible to attempt seed production. Tests of the value of the crop from the Muck Farm as seed, in comparison with special samples of certified seed, have been made at the Washington County Experiment Farm near Marietta. The results are shown in Table 13. The muck seed was fully as good as the certified seed in 1933 and 1935 but not as good in 1934. The inferiority of the muck seed in 1934 might be due to the premature ripening of the crop in 1933, which was one result of the severe June frost. The possibility of producing Cobbler seed on muck in Ohio needs further investigation, however, before it can be recommended as a commercial procedure.

TABLE 13.—Irish Cobblers from the Muck Crops Farm Used as Seed at Washington County Experiment Farm, in Comparison with Northern Certified Seed

Average yield from triplicated plots, in bushels per acre

Year of test	Seed from Muck Crops Farm		Average of several samples of certified seed	
	No. 1 grade	Total	No. 1 grade	Total
	Bu.	*Bu.*	*Bu.*	*Bu.*
1933	187	241	181	226
1934	149	234	182	260
1935	369	448	366	459
Average	235	308	243	315

SUMMARY AND RECOMMENDATIONS

Field experiments with potatoes have been conducted for four seasons at a Muck Crops Experiment Farm located in Hardin County. The aim of the work has been to determine the practicability of producing potatoes on muck soil in Ohio and to answer questions about the details of cultural practices.

Muck appears to be the best soil in Ohio for potatoes. The yields at the Muck Crops Experiment Farm have been higher than at farms located on Wooster silt loam or Chenango fine sandy loam.

Frosts are likely to be serious on muck soils. In 2 years out of 4, early May plantings at the Experiment Farm were severely injured by frosts in June. In 1934 in the eastern part of the State frost occurred August 30. To escape losses from frost it is advisable to plant in late May and to grow a short season variety such as the Irish Cobbler.

Irish Cobbler has given good yields from plantings May 20 to 25. Earlier plantings gave higher yields in the two seasons which were free from June frosts.

Russet Rural and White Rural matured about 2 weeks later than the Irish Cobbler, and, since early fall frosts have not occurred at the Experiment Farm, the Rurals have yielded as well as or better than the Cobbler. In one instance the Rurals recovered from a June frost better than the Cobbler. A shortcoming of the Rurals is a tendency to develop growth cracks in seasons favorable for rapid growth.

In the fertilizer test, potash was the only fertilizer constituent that gave large increases in yield. From the results to date, potash fertilizer alone at a rate supplying 270 pounds of potash (K_2O) per acre or an 0-9-36 mixture at the rate of 750 pounds per acre is recommended.

In depth-of-planting tests the highest yields resulted from a depth of 3 inches. At this depth and with shallow covering at the time of planting, Rhizoctonia has not appreciably reduced the stand when the seed was relatively free from Rhizoctonia or when infected seed was properly treated.

Because the plants grow very rapidly and because leaf hoppers and flea beetles have been abundant, it has been advisable to spray at weekly intervals during the period of rapid growth.

Both overhead and subirrigation have increased the yield. Subirrigation would seem to be practical on a field scale on muck soils.

In two years out of three Irish Cobblers from the Muck Farm were very satisfactory for seed for the early crop in southern Ohio. Although it seems from these tests that seed potatoes might be grown on muck in Ohio, the special problems involved in seed production have not been sufficiently studied to justify a recommendation at this time.

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